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Date: _Nov 29, 2001_ Express Mail Label No. _EV005366860US_

Inventor(s): James A. Proctor, Jr.

Attorney's Docket No.: 2479.1008-015

SYSTEM AND METHOD FOR CONTROLLING SIGNAL STRENGTH OVER A REVERSE LINK OF A CDMA WIRELESS COMMUNICATION SYSTEM

RELATED APPLICATIONS

This application is a continuation-in-part of Application No. 09/730,376, filed

5 December 5, 2000, which is a continuation of Application No. 09/088,413, filed June 1,

1998, now U.S. Patent No. 6,222,832, which is a continuation-in-part of Application

No. 08/992,760, filed December 17, 1997, and a continuation-in-part of Application No.

08/992,759, filed December 17, 1997, and a continuation-in-part of Application No.

09/030,049, filed February 24, 1998, and claims the benefit of U.S. Provisional

10 Application No. 60/250,908, filed on December 1, 2000, and Provisional Application

No. 60/251,148, filed December 4, 2000. The entire teachings of the above applications

are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The increasing use of wireless telephones and personal computers has led to a

15 corresponding demand for advanced telecommunication services that were once thought

to only be meant for use in specialized applications. In the 1980's, wireless voice

communication became widely available through the cellular telephone network. Such

services were at first typically considered to be the exclusive province of the businessman because of expected high subscriber costs. The same was also true for access to remotely distributed computer networks, whereby until very recently, only business people and large institutions could afford the necessary computers and wireline

5   access equipment. As a result of the widespread availability of both technologies, the general population now increasingly wishes to not only have access to networks such as the Internet and private intranets, but also to access such networks in a wireless fashion as well. This is particularly of concern for the users of portable computers, laptop computers, hand-held personal digital assistants and the like who would prefer to access

10   such networks without being tethered to a telephone line.

There still is no widely available satisfactory solution for providing low cost, broad geographical coverage, high speed access to the Internet, private intranets, and other networks using the existing wireless infrastructure. This situation is most likely an artifact of several unfortunate circumstances. For one, the typical manner of

15   providing high speed data service in the business environment over the wireline network is not readily adaptable to the voice grade service available in most homes or offices. Such standard high speed data services also do not lend themselves well to efficient transmission over standard cellular wireless handsets. Furthermore, the existing cellular network was originally designed only to deliver voice services. As a result, the

20   emphasis in present day digital wireless communication schemes lies with voice, although certain schemes such as CDMA do provide some measure of asymmetrical behavior for the accommodation of data transmission. For example, the data rate on an IS-95 forward traffic channel can be adjusted in increments from 1.2 kbps up to 9.6 kbps for so-called Rate Set 1 and in for increments from 1.8 kbps up to 14.4 kbps for

25   Rate Set 2.

Existing systems therefore typically provide a radio channel which can accommodate maximum data rates only in the range of 14.4 kilobits per second (kbps) at best in the forward direction. Such a low data rate channel does not lend itself directly to transmitting data at rates of 28.8 or even 56.6 kbps that are now commonly

available using inexpensive wireline modems, not to mention even higher rates such as the 128 kbps which are available with Integrated Services Digital Network (ISDN) type equipment. Data rates at these levels are rapidly becoming the minimum acceptable rates for activities such as browsing web pages. Other types of data networks using

5 higher speed building blocks such as Digital Subscriber Line (xDSL) service are just now coming into use in the United States. However, their costs have only been recently reduced to the point where they are attractive to the residential customer.

Although such networks were known at the time that cellular systems were originally deployed, for the most part, there is no provision for providing higher speed

10 ISDN- or xDSL-grade data services over cellular network topologies. Unfortunately, in wireless environments, access to channels by multiple subscribers is expensive and there is competition for them. Whether the multiple access is provided by the traditional Frequency Division Multiple Access (FDMA) using analog modulation on a group of radio carriers, or by newer digital modulation schemes the permit sharing of a

15 radio carrier using Time Division Multiple Access (TDMA) or Code Division Multiple Access (CDMA), the nature of the radio spectrum is that it is a medium that is expected to be shared. This is quite dissimilar to the traditional environment for data transmission, in which the wireline medium is relatively inexpensive to obtain, and is therefore not typically intended to be shared.

20 Other considerations are the characteristics of the data itself. For example, consider that access to web pages in general is burst-oriented, with asymmetrical data rate transmission requirements. In particular, the user of a remote client computer first specifies the address of a web page to a browser program. The browser program then sends this web page address data, which is typically 100 bytes or less in length, over the

25 network to a server computer. The server computer then responds with the content of the requested web page, which may include anywhere from 10 kilobytes to several megabytes of text, image, audio, or even video data. The user then may spend at least several seconds or even several minutes reading the content of the page before requesting that another page be downloaded. Therefore, the required forward channel

data rates, that is, from the base station to the subscriber, are typically many times greater than the required reverse channel data rates.

In an office environment, the nature of most employees' computer work habits is typically to check a few web pages and then to do something else for extended period of

5   time, such as to access locally stored data or to even stop using the computer altogether. Therefore, even though such users may expect to remain connected to the Internet or private intranet continuously during an entire day, the actual overall nature of the need to support a required data transfer activity to and from a particular subscriber unit is actually quite sporadic.

10   SUMMARY OF THE INVENTION

Problem Statement

What is needed is an efficient scheme for supporting wireless data communication such as from portable computers to computer networks such as the Internet and private intranets using widely available infrastructure. Unfortunately, even

15   the most modern wireless standards in widespread use such as CDMA do not provide adequate structure for supporting the most common activities, such as web page browsing. Due to IS-95 being circuit-switched, there are only a maximum of 64 circuit-switched users that can be active at one time. In practicality, this limit is difficult to attain, and 20 or 30 simultaneous users are typically used.

20   In addition, the existing CDMA system requires certain operations before a channel can be used. Both access and traffic channels are modulated by so-called long code pseudonoise (PN) sequences; therefore, in order for the receiver to work properly it must first be synchronized with the transmitter. The setting up and tearing down of channels therefore requires overhead to perform such synchronization. This overhead

25   results in a noticeable delay to the user of the subscriber unit.

An attractive method of increasing data rate for a given user is the sharing of channels in both the forward and reverse link direction. This is an attractive option,

especially with the ease of obtaining multiple access with CDMA; additional users can be supported by simply adding additional codes for the forward link, or code phases in the reverse link for an IS-95 system. Ideally, this subchannel overhead would be minimized so that when additional subchannels need to be allocated to a connection,

5   they are available as rapidly as possible.

To maintain synchronization, it is therefore advantageous to provide the sub-channels in such a way that the lowest possible speed connection is provided on a reverse link while at the same time maintaining efficient and fast ramp-up of additional code phase channels on demand. This in turn would maximize the number of available

10   connections while minimizing the impact on the overall system capacity.

Brief Description of the Invention

The present invention is a service option overlay for an IS-95-like CDMA wireless communication system which accomplishes the above requirements. In particular, a number of subchannels for a forward link are defined within a single

15   CDMA radio channel bandwidth, such as by assigning different orthogonal codes to each sub-channel. Multiple subchannels are defined on the reverse link by assigning different code phases of a given long pseudonoise (PN) code to each subchannel. The instantaneous bandwidth needs of each on-line subscriber unit are then met by dynamically allocating additional capacity on an as needed basis for each network layer

20   connection.

More recently, the cdma-2000 system provides a variable spreading factor to increase data rate rather than using additional long codes. Only a single long code is used, and different data rate are obtained by changing the chips per data bit or the length of the orthogonal code. Further, additional orthogonal codes within the code phases are

25   employed.

More particularly, the present invention efficiently provides a relatively large number of virtual physical connections between the subscriber units and the base stations on the reverse link for extended idle periods such as when computers connected

to the subscriber units are powered on, but not presently actively sending or receiving data. These maintenance subchannels permit the base station and the subscriber units to remain in phase and time synchronism. The power levels over the subchannels is regulated to minimize interference. This in turn allows fast acquisition of additional

5   capacity. The additional capacity can be obtained in several ways. Additional code phases, or long codes, may be employed. Further, additional orthogonal codes within the same code phase may be added, as described above. Finally, the spreading factor of the codes may be varied.

In an idle mode, the subscriber unit sends a synchronization or "heartbeat"

10   message on the maintenance subchannel at a data rate which need only be fast enough to allow the subscriber unit to maintain synchronization with the base station. The duration of the heartbeat signal is determined by considering several factors, including the capture or locking range of the code phase locking circuits in the receiver at the base station, by the power control rate that is required, and/or by the rate at which the request

15   indication needs to be sent, based on a maximum delay for which a channel may still be requested.

For example, the receiver typically has a PN code correlator running at the code chip rate. One example of such a code correlator uses a delay lock loop consisting of an early-late detector. A loop filter controls the bandwidth of the loop which in turn

20   determines how long the code correlator must be allowed to operate before it can guarantee phase lock. This loop time constant determines the amount of "jitter" that can be tolerated; phase lock is typically considered to be maintainable when this is equal to a fraction of a chip time, such as about 1/8 of a chip time.

The heartbeat messages are preferably sent in time slots formed on the

25   subchannels defined by the code phases. The use of time slotting allows a minimum number of dedicated base station receivers to maintain the idle reverse links. In particular, the reverse maintenance channel links are provided using multiple phases of the same long code as well as by assigning a time slot on such code to each subscriber

unit. This reduces the overhead of maintaining a large number of connections at the base station.

Because of the time slotted nature of the reverse maintenance channel, the base station receiver can also be time shared among these various reverse links. To permit this, during each time slot allocated to a particular subscriber unit, the base station receiver first loads information concerning the last known state of its phase lock such as the last known state of early-late correlators. It then trains the early-late correlators for the required time to ensure that phase lock is still valid, and stores the state of the correlators at the end of the time slot.

When additional capacity is required to meet bandwidth demand, the additional code phases are assigned in a predetermined phase relationship with respect to the locked code in order to minimize overhead transmissions which would otherwise be needed from the base station traffic channel processor. As a result, many thousands of idle subscriber units may be supported on a single CDMA reverse link radio channel while at the same time minimizing start up delay when channels must be allocated.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views.

FIG. 1 is a block diagram of a wireless communication system making use of a bandwidth management scheme according to the invention.

FIG. 2 is a diagram showing how subchannels are assigned within a given radio forward link frequency (RF) channel.

FIG. 3 is a diagram showing how subchannels are assigned within a given reverse link RF channel.

FIG. 4 is a state diagram for a reverse link bandwidth management function in the subscriber unit; and

FIG. 5 is a state diagram of the reverse link bandwidth management function in the base station.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Turning attention now to the drawings more particularly, FIG. 1 is a block

5   diagram of a system 100 for providing high speed data and voice service over a wireless connection by seamlessly integrating a digital data protocol such as, for example, Integrated Services Digital Network (ISDN) with a digitally modulated wireless service such as Code Division Multiple Access (CDMA).

The system 100 consists of two different types of components, including

10   subscriber units 101-1, 101-2, ..., 101-u (collectively, the subscriber units 101) and one or more base stations 170. The subscriber units 101 and base stations 170 cooperate to provide the functions necessary in order to provide wireless data services to a portable computing device 110 such as a laptop computer, portable computer, personal digital assistant (PDA) or the like. The base station 170 also cooperates with the subscriber

15   units 101 to permit the ultimate transmission of data to and from the subscriber unit and the Public Switched Telephone Network (PSTN) 180.

More particularly, data and/or voice services are also provided by the subscriber unit 101 to the portable computer 110 as well as one or more other devices such as telephones 112-1, 112-2 (collectively referred to herein as telephones 112). The

20   telephones 112 themselves may in turn be connected to other modems and computers which are not shown in FIG. 1. In the usual parlance of ISDN, the portable computer 110 and telephones 112 are referred to as terminal equipment (TE). The subscriber unit 101 provides the functions referred to as a network termination type 1 (NT-1). The illustrated subscriber unit 101 is in particular meant to operate with a so-called basic

25   rate interface (BRI) type ISDN connection that provides two bearer or "B" channels and a single data or "D" channel with the usual designation being 2B+D.

The subscriber unit 101 itself consists of an ISDN modem 120, a device referred to herein as the protocol converter 130 that performs the various functions according to

the invention including spoofing 132 and bandwidth management 134, a CDMA transceiver 140, and subscriber unit antenna 150. The various components of the subscriber unit 101 may be realized in discrete devices or as an integrated unit. For example, an existing conventional ISDN modem 120 such as is readily available from

5   any number of manufacturers may be used together with existing CDMA transceivers 140. In this case, the unique functions are provided entirely by the protocol converter 130 which may be sold as a separate device. Alternatively, the ISDN modem 120, protocol converter 130, and CDMA transceiver 140 may be integrated as a complete unit and sold as a single subscriber unit device 101. Other types of interface

10 connections such as Ethernet or PCMCIA may be used to connect the computing device to the protocol converter 130. The device may also interface to an Ethernet interface rather than an ISDN "U" interface.

The ISDN modem 120 converts data and voice signals between the terminal equipment 110 and 112 to format required by the standard ISDN "U" interface. The U

15 interface is a reference point in ISDN systems that designates a point of the connection between the network termination (NT) and the telephone company.

The protocol converter 130 performs spoofing 132 and basic bandwidth management 134 functions. In general, spoofing 132 consists of insuring that the subscriber unit 101 appears to the terminal equipment 110, 112 that is connected to the

20 public switched telephone network 180 on the other side of the base station 170 at all times. The bandwidth management function 134 is responsible for allocating and deallocating CDMA radio channels 160 as required. Bandwidth management 134 also includes the dynamic management of the bandwidth allocated to a given session by dynamically assigning sub-portions of the CDMA radio channels 160 in a manner which

25 is more fully described below.

The CDMA transceiver 140 accepts the data from the protocol converter 130 and reformats this data in appropriate form for transmission through a subscriber unit antenna 150 over CDMA radio link 160-1. The CDMA transceiver 140 may operate

over only a single 1.25 MHz radio frequency channel or, alternatively, in a preferred

embodiment, may be tunable over multiple allocatable radio frequency channels.

CDMA signal transmissions are then received and processed by the base station

equipment 170. The base station equipment 170 typically consists of multichannel

5   antennas 171, multiple CDMA transceivers 172, and a bandwidth management

functionality 174. Bandwidth management 174 controls the allocation of CDMA radio

channels 160 and subchannels, in a manner analogous to the subscriber unit 101. The

base station 170 then couples the demodulated radio signals to the Public Switch

Telephone Network (PSTN) 180 in a manner which is well known in the art. For

10 example, the base station 170 may communicate with the PSTN 180 over any number of

different efficient communication protocols such as primary rate ISDN, or other LAPD

based protocols such as IS-634 or V5.2.

It should also be understood that data signals travel bidirectionally across the

CDMA radio channels 160. In other words, data signals received from the PSTN 180

15 are coupled to the portable computer 110 in a forward link direction, and data signals

originating at the portable computer 110 are coupled to the PSTN 180 in a so-called

reverse link direction. The present invention involves in particular the manner of

implementing the reverse link channels.

Continuing to refer to FIG. 1 briefly, spoofing 134 therefore involves having the

20 CDMA transceiver 140 loop back these synchronous data bits over the ISDN

communication path to spoof the terminal equipment 110, 112 into believing that a

sufficiently wide wireless communication link 160 is continuously available. However,

only when there is actually data present from the terminal equipment to the wireless

transceiver 140 is wireless bandwidth allocated. Therefore, the network layer need not

25 allocate the assigned wireless bandwidth for the entirety of the communications session.

That is, when data is not being presented upon the terminal equipment to the network

equipment, the bandwidth management function 134 deallocates initially assigned radio

channel bandwidth 160 and makes it available for another transceiver and another

subscriber unit 101.

In order to better understand how bandwidth management 134 and 174 accomplish the dynamic allocation of radio channels, turn attention now to FIG.2. This figure illustrates one possible frequency plan for the wireless links 160 according to the invention. In particular, a typical transceiver 170 can be tuned on command to any 1.25

5   MHz channel within a much larger bandwidth, such as up to 30 MHz. In the case of location in an existing cellular radio frequency bands, these bandwidths are typically made available in the range of from 800 to 900 MHz. For personal communication systems (PCS) type wireless systems, the bandwidth is typically allocated in the range from about 1.8 to 2.0 GigaHertz (GHz). In addition, there are typically two matching

10   bands active simultaneously, separated by a guard band, such as 80 MHz; the two matching bands form forward and reverse full duplex link.

Each of the CDMA transceivers, such as transceiver 140 in the subscriber unit 101, and transceivers 172 in the base station 170, are capable of being tuned at any given point in time to a given 1.25 MHz radio frequency channel. It is generally

15   understood that such 1.25 MHz radio frequency carrier provides, at best, a total equivalent of about 500 to 600 kbps maximum data rate transmission within acceptable bit error rate limitations.

In contrast to this, the present invention subdivides the available approximately 500 to 600 kbps data rate into a relatively large number of subchannels. In the

20   illustrated example, the bandwidth is divided into sixty-four (64) subchannels 300, each providing an 8 kbps data rate. A given subchannel 300 is physically implemented by encoding a transmission with one of a number of different assignable pseudorandom codes. For example, the 64 subchannels 300 may be defined within a single CDMA RF carrier by using a different orthogonal code for each defined subchannel 300 for

25   example, for the forward link.

As mentioned above, subchannels 300 are allocated only as needed. For example, multiple subchannels 300 are granted during times when a particular ISDN subscriber unit 101 is requesting that large amounts of data be transferred. These

subchannels 300 are quickly released during times when the subscriber unit 101 is relatively lightly loaded.

The present invention relates in particular to maintaining the reverse link so that synchronization of the subchannels does not need to be reestablished each time that
5 channels are taken away and then granted back.

FIG. 3 is a diagram illustrating the arrangement of how the subchannels are assigned on the reverse link. It is desirable to use a single radio carrier signal on the reverse link to the extent possible to conserve power as well as to conserve the receiver resources which must be made available at the base station. Therefore, a single 1.2288
10 MHz band 350 is selected out of the available radio spectrum.

A relatively large number, N, such as 1000 individual subscriber units are then supported by using a single long pseudonoise (PN) code in a particular way. First, a number, p, of code phases are selected from the available 2^{42}-1 different long code phases. A given long code phase is unique to a particular subscriber unit and never
15 changes. As will be explained, this is also true for supplemental code phases as well. The code p phases shifts are then used to provide p subchannels. Next, each of the p subchannels are further divided into s time slots. The time slotting is used only during the idle mode, and provides two advantages; it reduces the numbers of "maintenance" receivers in the base station, and it reduces the impact to reverse channel capacity by
20 reducing transmit power and thus interference. Therefore, the maximum supportable number of supportable subscriber units, N, is p times s. During idle mode, use of the same PN code with different phases and time slots provides many different subchannels with permits using a single rake receiver in the base station 104.

In the above mentioned channel allocation scheme, radio resources are expected
25 to be allocated on an as-needed basis. However, consideration must also be given to the fact that normally, in order set up a new CDMA channel, a given reverse link channel must be given time to acquire code phase lock at the receiver. The present invention avoids the need to wait for each channel to acquire code phase lock each time that it is set up by several mechanisms which are describe more fully below. In general, the

technique is to send a maintenance signal at a rate which is sufficient to maintain code phase lock for each subchannel even in the absence of data.

The objective here is to minimize the size of each time slot, which in turn maximizes the number of subscribers that can be maintained in an idle mode. The size,

5   t, of each time slot is determined by the minimum time that it takes to guarantee phase lock between the transmitter at the subscriber unit and the receiver in the base station. In particular, a code correlator in the receiver must receive a maintenance or "heartbeat" signal consisting of at least a certain number of maintenance bits over a certain unit of time. In the limit, this heartbeat signal is sent by sending at least one bit from each

10   subscriber unit on each reverse link at a predetermined time, e.g., its designated time slot on a predetermined one of the N subchannels.

The minimum time slot duration, t, therefore depends upon a number of factors including the signal to noise ratio and the expected maximum velocity of the subscriber unit within the cell. With respect to signal to noise ratio, this depends on

15    $$Eb / (No + Io)$$

where Eb is the energy per bit, No is the ambient noise floor, and Io is the mutual interference from other coded transmissions of the other sub-channels on the reverse link sharing the same spectrum. Typically, to close the link requires integration over 8 chip times at the receiver, and a multiple of 20 times that is typically needed to

20   guarantee detection. Therefore, about 160 chip times are typically required to correctly receive the coded signal on the reverse link. For a 1.2288 MHz code, Tc, the chip time, is 813.33 ns, so that this minimum integration time is about 130 μs. This in turn sets the absolute minimum duration of a data bit, and therefore, the minimum duration of a slot time, t. The minimum slot time of 130 μs means that at a maximum, 7692 time slots

25   can be made available per second for each phase coded signal.

To be consistent with certain power control group timing requirements, the time slot duration can be relaxed somewhat. For example, in the IS-95 standard, a power

control group timing requirement requires a power output sample from each subscriber unit every 1.25 ms.

Once code phase lock is acquired, the duration of the heartbeat signal is determined by considering the capture or locking range of the code phase locking

5 circuits in the receiver at the base station. For example, the receiver typically has a PN code correlator running at the code chip rate. One example of such a code correlator uses a delay lock loop consisting of an early-late detector. A loop filter controls the bandwidth of this loop which in turn determines how long the code correlator must be allowed to operate before it can guarantee phase lock. This loop time constant

10 determines the amount of "jitter" that can be tolerated in the code correlator, such as about 1/8 of a chip time, Tc.

In the preferred embodiment, the system 100 is intended to support so-called nomadic mobility. That is, high mobility operation within moving vehicles typical of cellular telephony is not expected to be necessary. Rather, the typical user of a portable

15 computer who is active is moving at only brisk walking speeds of about 4.5 miles per hour (MPH). At 4.5 MPH, corresponding to a velocity of 6.6 feet per second, a user will move 101 feet in 1/8 of the 1/1.2288 MHz chip time (Tc). Therefore, it will take about 101 feet divided by 6.6 feet, or about 15 seconds for such a user to move distance which is sufficiently far for him to a point where the code phase synchronization loop

20 cannot be guaranteed to remain locked. Therefore, as long as a complete synchronization signal is sent for a given reverse link channel every 15 seconds, the reverse link loop will therefore remain in lock.

FIG. 4 is a state diagram for a reverse link bandwidth management function in the subscriber unit. In an idle mode 400, a first state 401 is entered in which the

25 subscriber unit receives a time slot assignment for its code phase reverse channel. This time slot is only used in the idle mode. The same long code phase is pre-assigned and is permanent to the subscriber unit.

In a next state 402, the heartbeat signal is sent in the assigned time slots. A state 403 is then entered in which the subscriber unit monitors its internal data buffers to

determine whether additional code phase channels are required to support the establishment of a reverse link with sufficient bandwidth to support an active traffic channel. If this is not the case, then the subscriber returns to state 402 and remains in the idle mode 400.

5   Prior to entering the Active state 405 from Idle mode 400, the subscriber unit must make a request to the base station. If granted, (step 403-b), processing proceeds to step 451, and if not granted, processing proceeds to step 402. However, the subscriber unit knows that it is assigned code phase channels in a predetermined relationship to the code phase channel of its fundamental channel, i.e.,

10      $$P_{n+1} = \mathscr{F} \{P_o\}$$

where P_{n+1} is the code phase for the new channel (n+1), and P_o is the code phase assigned to the fundamental channel for the particular subscriber. Such a code phase relationship $\mathscr{F}$ may be, for example, to select uniformly from the available 2^{42} codes, every $2^{42} / 2^{10}$ 'th or every 2^{32}'th code phase in a system which is supporting 1024 (2^{10})

15   reverse links, for a single subscriber.

As described above the reverse link available capacity and related power control allow additional capacity by adding orthogonal codes rather than additional code phases and by varying the spreading factor, in addition to employing new codes.

A number, C, of these new code phases are therefore instantaneously calculated

20   based simply upon the number of additional code phase channels, and without the need to require code phase synchronization for each new channel.

After step 452 is processed, a request is made for code phase channels. If granted (step 452-b), processing proceeds to step 453, and if not granted, processing proceeds to step 451 in order to process the additional channel requests. In a next state

25   453, the subscriber unit begins transmitting its data on its assigned code phase channels. In state 454, it continues to monitor its internal data buffers and its associated forward access channel to determine when to return to the idle mode 400, to to state 451, to

determine if new code phase channels must be assigned, or to state 455, where they are deallocated.

FIG. 5 is a state diagram of idle mode processing in the reverse link management function in the base station 104. In a first state 501, for each idle subscriber unit 101, a

5   state 502 is entered in which a stored state of the correlators for the present time slot (p,s) from a previous synchronization session is read. In a next state 503, an early-late correlator is retrained for the time slot duration, t. In a next state 504, the correlator state is stored; in state 505, the loop is continued for each subscriber.

EQUIVALENTS

10   While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

For example, instead of ISDN, other wireline and network protocols may be

15   encapsulated, such as xDSL, Ethernet, and X.25, and therefore may advantageously use the dynamic wireless subchannel assignment scheme described herein.

Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described specifically herein. Such equivalents are intended to be encompassed in the

20   scope of the claims.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.